# ECE 5235/ 7235 INFO 5235 - SUSTAINABLE URBAN AND ENERGY SYSTEMS

## OBJECTIVES:

This course describes energy delivery infrastructures and their operations, with the objective of identifying roadblocks to a more sustainable system. The course also explores future technologies, that apply advances in machine learning and optimization, to curb greenhouse gas emissions, reducing the dependency of the system on fossil-fuel power generators and promoting renewable integration. The models introduced capture electric power demand driven by human consumption in urban environments and key enterprises, the cyber-physical infrastructure to transport electric energy, and how the demand is economically met, by describing how energy markets operate.

## OUTCOMES

The outcomes of this course are as follows. Students will learn:

1. Models for demand, supply and transfer of electricity characterizing energy infrastructures.
2. The decision model and operations of energy delivery systems.
3. The design opportunities for new decision and market models that exist, leveraging electrification of energy uses and advances in digital technology to incorporate more renewable power, storage and flexible demand, to improve emissions.
4. Advanced numerical methods in machine learning and optimization that to improve system outcomes in terms of sustainability.

## INSTRUCTION

- **Instructor:** Prof. Anna Scaglione, office: Bloomberg 265
- **Teaching Assistant:** -
- **Course schedule:** T-T 11:45 - 12:55pm
- Office hours: Tuesdays 1:30pm or upon demand

## CREDITS

3 credit hours

## REQUIREMENTS

The course requires good understanding of algebra and calculus. It will review basic concepts of system theory and optimization. Prior knowledge is a plus.

## READING MATERIAL

The course will refer to journal papers to complement the course slides.

## SPECIFIC TOPICS

1. **Preliminaries**
    a. Overview of the course
        i. Demand for power
        ii. Options for power generation and delivery
2. **Electrical Power Transmission and Distribution Systems**
    a. Review of basic systems theory
    b. Principles of electrical power transfer
        i. Voltage, Current and transmission lines
        ii. Two ports models
    c. AC signals complex representation/phasors
    d. Power flow equations
    e. Congestion constraints
3. **Operations: Energy Management Systems Models**
    a. Power flow equations
        i. AC, and Linearizations
    b. Data: Monitoring of electrical power systems
        i. Review of classical Non-Linear Regression and Non-Linear Least Square
        ii. Advanced methods: Graph Signal Processing and Graph Neural Networks
        iii. State estimation
            1. Types of Sensor measurements
            2. Classic and advanced methods
    c. Optimization and control: Optimal Power Flow
        i. AC OPF non-convex solvers and convex approximation and relaxations
4. **Stochastic demand and generation**
    a. Brief review of probability and stochastic processes
    b. Forecasting tools
    c. Models and forecasting techniques
        i. Electricity Demand Forecasting
        ii. Solar Power Modeling and Forecasting
        iii. Wind Power Modeling and Forecasting
5. **Energy Markets**
    a. Economic Dispatch of Electrical Power,
        i. The Whole Sale Market of Electricity Optimization
            1. Day ahead, real time
            2. Ancillary services
6. **Emerging Stochastic Optimization frameworks**
7. **Demand response modeling**
    a. Demand Response programs
        i. Load control models via direct control
        ii. Load control models via dynamic pricing
    b. Aggregate demand models

        i. Controllable demand models
    c. Electric storage
8. **Discussion on open problems**

## ASSIGNMENTS

The assignments will consist in modeling, simulation, and numerical implementation of algorithms to analyze network data. They will be available online and should be submitted electronically. There will be typically weekly assignment in the course, 2 Midterms to be completed at home in two weeks.

- Homework/Quizzes - 30% of the grade
- Midterms - 35% of the grade
- Final Project - 35% of the grade

***Due dates:*** *Unless otherwise indicated on Canvas, the weekly assignments are due a week from when they are assigned and the biweekly ones two weeks after they are assigned.*

### GRADES SCALE

The grade scale used to grade is from 0 to 4, indicating

- 0 = nothing to work with for assigning a grade
- 1= poor
- 2= fair
- 3= good
- 4 = excellent

The final grade average will be rescaled in the range [0,100] and the following thresholds will be used for assigning the letter grade:

| Letter Grade | Percentage | Points Range | Letter Grade | Percentage |
|---|---|---|---|---|
| A+ | 100 – 96.0% | M– 0.96*M | C+ | 72.9% -67% |
| A | 95.9 – 93.0% | 0.969*M–0.92*M | C | 67% -56% |
| A- | 92.9 – 89% | Etc. | D | 55% – 50% |
| B+ | 88.9 – 85.0% | | E | 49%–43% |
| B | 84.9 – 80.0% | | F | |
| B- | 79.9 – 73% | | | |

### LATE OR MISSED ASSIGNMENTS

Notify the instructor BEFORE an assignment is due if an urgent situation arises and the assignment will not be submitted on time. You can miss one of the homework without impact on your grade because of an emergency. You can gain 10% over the grade for early submissions (24h before the deadline) and loose 10% for every day the assignment is late for up to 2 days.

### Student Success

To be successful:

- read announcements
- read and respond to course email messages as needed
- complete assignments by the due dates specified

- communicate regularly with your instructor and peers
- create a study and/or assignment schedule to stay on track

### Attendance/Participation

Preparation for class means reading the assigned readings, practice problems and reviewing all information required for that week. Attendance for students enrolled in this course means in on a regular basis attending classes, logging on to Canvas to check for assignments and participating in all the pertinent activities that are posted in the course.

Attendance feedback to the instructor is also part of the course attendance

### Course Time Commitment

The course requires you to spend time preparing and completing assignments. A three-credit course requires 135 hours of student work. Therefore, expect to spend approximately 7-8 hours a week preparing for and actively participating in this course.

### Students with Disabilities

Please make sure you notify the instructor, and Students for Disabilities serves at the beginning of the course regarding special needs: http://sds.cornell.edu.

### Communicating With the Instructor

This course uses a "three before me" policy regarding student to faculty communications. When questions arise, please remember to check these three sources for an answer before asking me to reply to your individual questions:

1. Course syllabus
2. Announcements in Canvas
3. Office hours